

Neurologic Manifestations and Outcome of West Nile Virus Infection

James J. Sejvar, MD

Maryam B. Haddad, MSN, MPH, FNP

Bruce C. Tierney, MD

Grant L. Campbell, MD, PhD

Anthony A. Marfin, MD, MPH

Jay A. Van Gerpen, MD

Aaron Fleischauer, PhD

A. Arturo Leis, MD

Dobrivoje S. Stokic, MD

Lyle R. Petersen, MD, MPH

MOST HUMAN INFECTIONS with West Nile virus (WNV) are subclinical or manifest as a mild febrile illness, but a small proportion of patients (<1%) develop acute neurologic illness.¹⁻⁴ Although recent WNV outbreaks have been associated with severe neurologic disease,¹⁻⁵ retrospective studies have failed to identify clinical features that distinguish WNV from other viral encephalitis.^{1,5-9} The US outbreak of WNV in 2002¹⁰ presented an opportunity to assess neurologic manifestations, laboratory and neurodiagnostic findings, and outcome associated with WNV infection.^{1,7,11}

METHODS

From August 1 to September 2, 2002, patients from St Tammany Parish, La, with suspected WNV infection were identified through state-based surveillance at local hospitals and regional medical centers. Suspected WNV infection was defined as illness with evidence of an acute infectious process (eg, temperature $\geq 39^{\circ}\text{C}$; elevated white blood cell

Context The neurologic manifestations, laboratory findings, and outcome of patients with West Nile virus (WNV) infection have not been prospectively characterized.

Objective To describe prospectively the clinical and laboratory features and long-term outcome of patients with neurologic manifestations of WNV infection.

Design, Setting, and Participants From August 1 to September 2, 2002, a community-based, prospective case series was conducted in St Tammany Parish, La. Standardized clinical data were collected on patients with suspected WNV infection. Confirmed WNV-seropositive patients were reassessed at 8 months.

Main Outcome Measures Clinical, neurologic, and laboratory features at initial presentation, and long-term neurologic outcome.

Results Sixteen (37%) of 39 suspected cases had antibodies against WNV; 5 had meningitis, 8 had encephalitis, and 3 had poliomyelitis-like acute flaccid paralysis. Movement disorders, including tremor (15 [94%]), myoclonus (5 [31%]), and parkinsonism (11 [69%]), were common among WNV-seropositive patients. One patient died. At 8-month follow-up, fatigue, headache, and myalgias were persistent symptoms; gait and movement disorders persisted in 6 patients. Patients with WNV meningitis or encephalitis had favorable outcomes, although patients with acute flaccid paralysis did not recover limb strength.

Conclusions Movement disorders, including tremor, myoclonus, and parkinsonism, may be present during acute illness with WNV infection. Some patients with WNV infection and meningitis or encephalitis ultimately may have good long-term outcome, although an irreversible poliomyelitis-like syndrome may result.

JAMA. 2003;290:511-515

www.jama.com

count; or cerebrospinal fluid [CSF] pleocytosis) along with clinical evidence of meningitis, encephalitis, or acute focal weakness (BOX). Infection with WNV was confirmed if WNV-specific antibodies were detected in acute-phase serum or CSF samples by IgM antibody-capture enzyme-linked immunosorbent assay (MAC-ELISA)¹² and were confirmed by plaque-reduction neutralization assay.¹³

Eligible enrollees were assessed on presentation to medical care. Patients were approached under the auspices of a public health event; oral consent was obtained. Standardized case histories and initial symptoms and signs were collected. One neurologist (J.J.S.) examined each patient; a second neurologist verified findings for 7 patients. Laboratory results, neuroimaging and

electrophysiologic findings were recorded and updated 1 week following initial assessment, during repeat neurologic evaluation.

Approximately 8 months later (March 15-April 4, 2003), patients with confirmed WNV infection were reexamined. The Centers for Disease Control and Prevention institutional review

Author Affiliations: Division of Viral and Rickettsial Diseases (Dr Sejvar) and Division of Vector-Borne Infectious Diseases (Drs Campbell, Marfin, and Petersen), National Center for Infectious Diseases, and Epidemic Intelligence Service, Epidemiology Program Office (Drs Tierney and Fleischauer and Ms Haddad), Centers for Disease Control and Prevention, Atlanta, Ga; Department of Neurology, Ochsner Clinic, New Orleans, La (Dr Van Gerpen); Center for Neuroscience and Neurological Recovery, Methodist Rehabilitation Center, Jackson, Miss (Drs Leis and Stokic).

Corresponding Author and Reprints: James J. Sejvar, MD, Division of Viral and Rickettsial Diseases, National Center for Infectious Diseases, Centers for Disease Control and Prevention, 1600 Clifton Rd, MS A-39, Atlanta, GA 30333 (e-mail: zea3@cdc.gov).

See also p 524 and Patient Page.

Box. Diagnostic Criteria**West Nile Meningitis**

- A. Clinical signs of meningeal inflammation, including nuchal rigidity, Kernig or Brudzinski sign, or photophobia or phonophobia
- B. Additional evidence of acute infection, including 1 or more of the following: fever ($>38^{\circ}\text{C}$) or hypothermia ($<35^{\circ}\text{C}$); cerebrospinal fluid pleocytosis (≥ 5 leukocytes/ mm^3); peripheral leukocyte count $>10000/\text{mm}^3$; neuroimaging findings consistent with acute meningeal inflammation

West Nile Encephalitis

- A. Encephalopathy (depressed or altered level of consciousness, lethargy, or personality change lasting ≥ 24 hours)
- B. Additional evidence of central nervous system inflammation, including 2 or more of the following: fever ($\geq 38^{\circ}\text{C}$) or hypothermia ($\leq 35^{\circ}\text{C}$); cerebrospinal fluid pleocytosis (≥ 5 leukocytes/ mm^3); peripheral leukocyte count $>10000/\text{mm}^3$; neuroimaging findings consistent with acute inflammation (with or without involvement of the meninges) or acute demyelination; presence of focal neurologic deficit; meningismus (as defined in A); electroencephalography findings consistent with encephalitis; seizures, either new onset or exacerbation of previously controlled

Acute Flaccid Paralysis

- A. Acute onset of limb weakness with marked progression over 48 hours
- B. At least 2 of the following: asymmetry to weakness; areflexia/hyporeflexia of affected limb(s); absence of pain, paresthesia, or numbness in affected limb(s); cerebrospinal fluid pleocytosis (≥ 5 leukocytes/ mm^3) and elevated protein levels (≥ 45 mg/dL); electrodiagnostic studies consistent with an anterior horn cell process; spinal cord magnetic resonance imaging documenting abnormal increased signal in the anterior gray matter

board approved the follow-up protocol. Using a standardized questionnaire, patients were queried about symptoms, functional status, and ability to perform daily activities. The neurologic assessment was repeated (J.J.S.).

Exact Wilcoxon rank-sum test was used for comparison of medians. Statistical analyses were performed using SAS, version 8.1 (SAS Institute, Cary, NC).

RESULTS**Clinical Features**

Of 39 patients evaluated, WNV infection was confirmed in 16 patients. Discharge diagnoses of the 23 patients without WNV infection included viral meningitis ($n=6$), headache ($n=5$), viral encephalitis ($n=4$), unspecified viral illness ($n=4$), and encephalopathy ($n=1$). Final diagnoses were unavailable for 3 patients.

Eleven (69%) of the 16 WNV-seropositive patients were white (population of St Tammany Parish is 74% white), and 9 were male. Of the 16 pa-

tients, 5 were classified as having West Nile meningitis (WNM), 8 as having West Nile encephalitis (WNE), and 3 as having acute flaccid paralysis (AFP) (TABLE). One patient classified with AFP also had encephalitis. Information regarding the initial presentation of 3 patients with AFP had been reported previously.^{14,15} Patients with WNM (median age, 35 years) were younger than those with WNE (median, 70 years) ($P=.003$). One patient with severe WNE had systemic lupus erythematosus and was treated with corticosteroids. No other WNV-seropositive patient had a clear condition indicating immunocompromise.

The 16 WNV-seropositive patients were hospitalized a median of 2.5 days after symptom onset; the median hospital stay was 12 days (Table). Five patients spent a median of 10 days (range, 3-19 days) in intensive care.

Self-reported symptoms were similar among all patients presenting with possible WNV infection (Table). Eleven

of the 15 WNV-seropositive patients with headache described it as frontal/retro-orbital, and 5 of the 16 WNV-seropositive patients reported a rash. Fifteen WNV-seropositive patients reported "shakiness" or "twitching," with 5 describing it as notable in the evening prior to sleep. Among patients with WNE, the most common complaints were behavioral or personality changes, manifested as irritability, confusion, or disorientation. Two patients with WNM and 1 patient with WNE reported difficulty with balance and gait. Five patients reported weakness, which was focal in the 3 patients developing AFP and was generalized in 2 patients.

The 8 patients with WNE had a mean admission Glasgow Coma Scale score of 11 (range, 4T [intubated] to 15). A median of 3 days passed between symptom onset and changes in mental status. Cranial nerve and bulbar abnormalities were observed in several patients with WNE. Results of formal strength testing displayed mild-to-moderate diffuse weakness in 4 patients and focal weakness in the 3 patients with AFP. New sensory abnormalities were not observed. Four patients with WNE and 1 patient with WNM displayed abnormal hyperreflexia; the 3 patients with AFP all had areflexia or hyporeflexia of the affected limbs.

Dyskinesias (ie, movements including tremor, myoclonus, and features of parkinsonism) were observed in 15 of the 16 WNV-seropositive patients (Table). Tremor was observed in 15 patients; 9 had onset of tremor after day 5 of illness. Tremor in all 15 patients was static or kinetic, asymmetric, and involved the upper extremities. Two patients additionally displayed intentional movement dysmetria. Myoclonus was directly observed in 10 patients. Parkinsonism was observed in all 3 patients with AFP, 6 of 8 patients with WNE, and 2 of 5 patients with WNM. Resting tremor was not observed. Seizures were documented using electroencephalography in 1 patient with WNE.

All 3 patients with AFP had asymmetric limb weakness within 48 hours of initial symptom onset. Pain, pares-

thesias, or acute sensory loss were not observed. All 3 patients experienced bowel and bladder dysfunction.

Neuroimaging and Electrophysiologic Studies

None of the WNV-seropositive patients showed acute abnormalities on computed tomography. Magnetic resonance imaging of the brain was performed on 10 of the 16 patients: the findings showed nonacute abnormalities in 8 patients and bilateral, focal lesions in the basal ganglia, thalamus, and

pons on T2- and diffusion-weighted sequences in 2 severely ill patients with WNE (FIGURE). Findings of magnetic resonance imaging of the cervical, thoracic, and lumbosacral spine for the 2 patients with AFP with lower extremity involvement showed enhancement of the cauda equina and nerve root clumping consistent with meningitis. Findings of magnetic resonance images of the cervical and thoracic spine in a patient with AFP with right arm involvement showed diffuse degenerative changes without spinal cord abnormalities.

Electroencephalograms were obtained for 7 patients with WNE. Abnormal findings included electrographic seizures in 1 patient, focal sharp waves in 1 patient, and diffuse irregular slow waves in 6 patients. No correlation between electroencephalographic findings and the presence of myoclonus or tremor was observed.

Electromyographs and nerve conduction studies were performed on the 3 WNV-seropositive patients and 1 WNV-seronegative patient with asymmetric weakness from 3 to 42 days after onset

Table. Clinical Features

	West Nile Meningitis (n = 5)	West Nile Encephalitis (n = 8)	Acute Flaccid Paralysis (n = 3)	West Nile Virus Seropositive Patients (n = 16)	West Nile Virus Seronegative Controls (n = 23)
Age, y, median (range)	35 (20 to 39)	70 (46 to 81)	56 (46 to 69)	57 (20 to 81)	32 (2 to 65)
Days from illness onset to presentation, median (range)	5 (3 to 7)	1.5 (–3 to –14)*	2 (2 to 4)	2.5 (–3 to –14)	4 (0 to 21)
Self-reported symptoms, No. (%)					
Fever	5 (100)	8 (100)	3 (100)	16 (100)	22 (96)
Headache	5 (100)	8 (100)	2 (66)	15 (94)	22 (96)†
Nausea	4 (80)	5 (62)	2 (66)	11 (69)	17 (74)†
Neck pain	4 (80)	4 (50)	1 (33)	9 (56)	17 (74)†
Vomiting	4 (80)	6 (75)	2 (66)	12 (75)	12 (52)
Myalgias/body aches	4 (80)	5 (63)	2 (66)	11 (69)	16 (73)†
Chills/rigors	3 (60)	4 (50)	2 (66)	9 (56)	13 (57)
Low back pain	2 (40)	3 (38)	0	5 (31)	9 (41)†
Weakness	1 (20)	1 (13)	3 (100)	5 (31)	9 (41)
Neurologic findings, No.(%)					
Altered mental status	0	8 (100)	1 (33)	9 (56)	4 (17)
Weakness	0	4 (50)	3 (100)	7 (47)	3 (13)
Tremor	4 (80)	8 (100)	3 (100)	15 (94)	2 (8)
Myoclonus	1 (20)	3 (38)	1 (33)	5 (31)	1 (4)
Parkinsonism	2 (40)	6 (75)	3 (100)	11 (69)	0
Rigidity	2 (40)	6 (75)	3 (100)	11 (69)	0
Bradykinesia	2 (40)	5 (63)	2 (67)	9 (56)	0
Postural instability	2 (40)	4 (50)	0	6 (38)	0
Nuchal rigidity	5 (100)	5 (63)‡	1 (33)	11 (69)	4 (17)†
Rotatory nystagmus	0	2 (25)	0	2 (13)	0
Dysphagia	0	4 (50)	0	4 (25)	0
Absent corneal/gag reflex	0	3 (38)	0	3 (19)	1 (4)
Ataxic/apneustic breathing	0	2 (25)	0	2 (13)	2 (8)
Babinski sign	0	3 (38)	0	3 (19)	3 (13)
Laboratory results					
Leukocyte count at admission, $\times 10^3/\text{mm}^3$	13.9 (9.8 to 17.1)	7.6 (3.5 to 18.2)	11.8 (9.5 to 13.0)	9.9 (3.5 to 18.2)	7.3 (5.6 to 16.2)
Initial CSF leukocyte count, cells/ mm^3	24 (1 to 2317)	62 (0 to 1168)§	143 (140 to 329)	140 (0 to 2317)	2 (0 to 189)
Initial CSF protein, mg/dL	57 (40 to 157)	78 (51 to 194)§	116 (75 to 234)	78 (40 to 234)	45 (13 to 295)
Initial CSF glucose, mg/dL	68 (44 to 113)	54 (37 to 102)§	74 (60 to 119)	60 (37 to 119)	86 (54 to 156)
Initial CSF lymphocytes, %	21 (2 to 57)	25 (0 to 83)§	68 (42 to 95)	26 (0 to 95)	63 (4 to 100)
Days hospitalized, median (range)	5 (4 to 8)	15.5 (5 to 35)	14 (7 to 19)	12 (4 to 36)	7 (1 to 66)

Abbreviation: CSF, cerebrospinal fluid. SI conversion: For glucose, to convert mg/dL to mmol/L, multiply by 0.06555.

*Patient hospitalized for unrelated condition before onset of symptoms associated with acute West Nile virus infection.

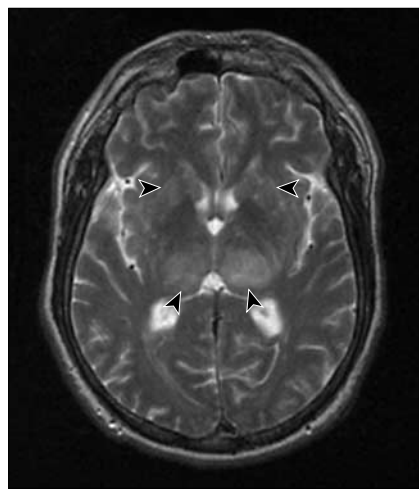
†Patients who were comatose were not assessed (n = 22).

‡Patients who were comatose were not assessed (n = 7).

§n = 7.

||n = 16.

Figure. T2-Weighted Axial Magnetic Resonance Image From a Patient With West Nile Virus Encephalitis



The image displays bilateral increased signal in the posterior thalami (lower 2 arrowheads) and focal areas of striatum (upper 2 arrowheads).

of weakness. All WNV-seropositive patients demonstrated findings consistent with a severe, asymmetric process affecting anterior horn cells. The WNV-seronegative patient displayed overall findings consistent with a combined axonal and demyelinating neuropathy (ie, Guillain-Barré syndrome).

Outcome and 8-Month Follow-up

One patient with WNE remained comatose and ventilator-dependent until death, which occurred 2.5 months after onset of illness. All surviving patients eventually were discharged home. However, 3 patients with AFP and 2 patients with WNE were initially discharged to long-term rehabilitation facilities. At 8 months, 11 patients were home and functioning independently; 3 were home, but dependent; and 1 was undergoing rehabilitation.

At 8 months, 10 WNV-seropositive patients reported persistent fatigue, 3 persistent myalgias, and 2 persistent headache. Four patients with WNE reported persistent cognitive deficits, including difficulties with memory, short-term recall, and slowness of thought. One patient had mental status scores significantly below baseline levels.

Follow-up neurologic examination of the 15 WNV-seropositive patients who survived revealed no neurologic deficits in the 5 patients with WNM. Among patients with WNE and AFP, tremor was present in 5 patients and parkinsonism in 5. A postural and/or kinetic tremor was observed in 5 patients following recovery from WNE, and in 1 patient, it was severe enough to interfere with grooming and eating. Parkinsonism persisted in 5 of the 11 patients. In all but 1 patient (the patient with underlying systemic lupus erythematosus), parkinsonism was mild and did not interfere with daily activities. One patient with WNE with severe initial parkinsonism and postural instability was ambulatory with a walker for 4 months following illness onset, but by 6 months was able to climb ladders at work. Eight-month follow-up examination demonstrated only minimal postural instability and bradykinesia. The 8-month follow-up examination revealed 2 patients who demonstrated myoclonus of the upper extremities and face.

Five of 7 patients with severe encephalitis, as characterized by an initial Glasgow Coma Scale score of 12 or less or an initial mental status score of 2 SDs below normal for age, had favorable outcomes, defined as achieving or exceeding their level of functioning before illness. Two patients with particularly guarded prognoses during acute illness were functioning at baseline level by 6 months, with no residual symptoms. Recovery to normal or near-normal functioning occurred within 4 months in all cases of improvement.

Patients with AFP showed no improvement in limb weakness. Bladder symptoms in the patients with AFP had resolved. Electromyographs and nerve conduction studies performed at the 8-month follow-up examination revealed chronic denervation and motor axon loss in affected limbs. One patient with AFP experienced continued severe dyspnea. Chest and diaphragmatic fluoroscopy performed 3 months after illness onset revealed right hemidiaphragmatic paralysis consistent with central nervous system etiologic findings.

Patients with AFP reported the lowest overall functioning scores and had the lowest scores on both Barthel and modified Rankin scoring systems (data not shown). Five of 7 patients who survived WNE and 4 of 5 patients who survived WNM reported normal functional scores (data not shown). Seven of the 10 patients who were employed before WNV infection returned to work within 4 months following hospital discharge. Five patients, including all 3 with AFP, described continuing difficulties with daily activities, such as grooming, housekeeping, and mobility. All patients with AFP required use of a wheelchair for ambulation, and 2 patients who had been independently mobile before infection required walkers following recovery from WNE.

COMMENT

Movement disorders, in particular tremor, myoclonus, and parkinsonism, were prominent among WNV-seropositive patients, but uncommon among WNV-seronegative patients. While tremor and myoclonus have been documented prospectively in patients with St Louis encephalitis virus¹⁶⁻¹⁸ or other viral infections,^{19,20} they have not been described in contemporary WNV studies.^{1,2,3,5,6,9,21} Documentation of these findings in 15 of 16 WNV-seropositive patients suggests that these findings have diagnostic relevance.

Previous immunohistological assessments have detected WNV in the basal ganglia, thalamus, and pons in patients with severe encephalitis,²² suggesting the possibility of viral involvement of these structures with resultant parkinsonism and tremor. Magnetic resonance imaging findings in 2 patients correlated clinically with the findings of parkinsonism and tremor; however, in 8 patients, parkinsonian features were present without abnormal findings on magnetic resonance imaging. Parkinsonism has been observed with Japanese encephalitis virus infection,²³⁻²⁶ a related flavivirus. Some prior studies have suggested long-term persistence of signs,²³⁻²⁵ while others have reported parkinsonism as a more transient feature.²⁷ In our study, the pa-

tient with severe persistent parkinsonism at 8-month follow-up had shown persistence of abnormalities in the basal ganglia, thalamus, and substantia nigra on magnetic resonance imaging.

All patients with WNM had favorable outcome; all returned to work and reported normal or near-normal functioning at 8-month follow-up. In addition, 5 patients with severe WNE had excellent outcomes, achieving premorbid levels of functioning without residual disability within 4 months of illness. Severe encephalitis caused by other viral agents²⁸⁻³⁰ may often be associated with severe persistent cognitive and neurologic deficits; by comparison, this group of patients with WNE displayed a low incidence of persistent sequelae. Severity of initial encephalopathy does not necessarily portend poor long-term outcome in all patients.

Two of the 3 patients with AFP developed AFP without associated encephalopathy or meningismus. Clinical findings and electrodiagnostic data suggested involvement of anterior horn cells of the spinal cord, resulting in a poliomyelitis-like syndrome.^{14,15,31-32} At 8 months, none of the patients had improvement in weakness, and electromyographic data suggested permanent motor neuron loss, indicating that significant recovery in weakness is unlikely. Persistent dyspnea in 1 patient with AFP is most likely due to poliomyelitis-like diaphragmatic and intercostal muscle weakness with respiratory failure.³³⁻³⁵

We conclude that movement disorders, particularly tremor, myoclonus, and parkinsonism, may be underrecognized manifestations of acute WNV illness and have a generally favorable prognosis. However, complaints of persistent fatigue, headache, and myalgia are common. Long-term outcome of patients with WNE is variable, and severe initial encephalopathy did not necessarily portend poor prognosis. A poliomyelitis-like syndrome can occur without associated meningitis or encephalitis and has poor long-term outcome.

Author Contributions: *Study concept and design:* Sejvar, Haddad, Tierney, Campbell, Marfin, Petersen. *Acquisition of data:* Sejvar, Haddad, Tierney, Campbell, Van Gerpen, Leis, Stokic.

Analysis and interpretation of data: Sejvar, Haddad, Marfin, Van Gerpen, Fleischauer, Stokic, Petersen. *Drafting of the manuscript:* Sejvar, Haddad, Tierney, Petersen.

Critical revision of the manuscript for important intellectual content: Sejvar, Campbell, Marfin, Van Gerpen, Fleischauer, Leis, Stokic, Petersen.

Statistical expertise: Sejvar, Haddad, Fleischauer.

Obtained funding: Marfin.

Administrative, technical, or material support: Sejvar, Haddad, Campbell, Marfin, Van Gerpen, Petersen.

Study supervision: Petersen.

Funding/Support: The study was supported by program funds for West Nile virus through the Department of Health and Human Services, Centers for Disease Control and Prevention.

Acknowledgment: We wish to acknowledge the contributions of the following individuals and institutions, whose assistance made this project possible: Case-series participants and their families; R. Ratard, MD, state epidemiologist, A. Vacari, DVM, E. Brewer, MD, J. Hand, MPH, R. Essien, MSHCN, Louisiana Office of Public Health; M. Bunning, DVM, P. Collins, MS, S. Montgomery, DVM, MPH, A. Kipp, MPH, C. Chow, MD, D. Martin, PhD, Division of Vector-Borne Infectious Diseases, National Center for Infectious Diseases, Centers for Disease Control and Prevention; D. Cashen, RN, Lakeview Regional Medical Center, Covington, La; K. Moise, RN, St. Tammany Parish Hospital, Covington, La; P. Vaccaro, RN, North Oaks Regional Medical Center, Hammond, La; B. Meiche, RN, North Shore Regional Medical Center, Slidell, La; T. Croney, RN, Slidell Memorial Hospital, Slidell, La; J. Maffei, MD, D. Friloux, RN, Charity Hospital, New Orleans, La; D. Baumgarten, MD; C. Bitar, MD; M. Culasso, MD; R. Duffour, MD; J. Fitzpatrick, MD; S. Ganji, MD; T. Hall, MD; R. Houser, MD; S. Kemmerly, MD; J. LeFran, MD; R. Millett, MD; C. Nine-Montanez, MD; R. Peltier, MD, S. Raina, MD, G. Reddi, MD, R. Saguiguit, MD.

REFERENCES

- Campbell G, Marfin A, Lanciotti R, Gubler D. West Nile virus. *Lancet Infect Dis*. 2002;2:519-529.
- Tsai T, Popovici F, Cernescu C, Campbell G, Nedelcu N. West Nile encephalitis epidemic in southeastern Romania. *Lancet*. 1998;352:767-771.
- Chowers M, Lang R, Nassar F, et al. Clinical characteristics of the West Nile fever outbreak, Israel, 2000. *Emerg Infect Dis*. 2001;7:675-678.
- Centers for Disease Control and Prevention. Serosurveys for West Nile virus infection—New York and Connecticut counties, 2000. *MMWR Morb Mortal Wkly Rep*. 2001;50:37-39.
- Platonov A, Shipulin G, Shipulina O, et al. Outbreak of West Nile virus infection, Volgograd Region, Russia, 1999. *Emerg Infect Dis*. 2001;7:128-132.
- Mostashari F, Bunning M, Kitsutani P, et al. Epidemic West Nile encephalitis, New York, 1999. *Lancet*. 2001;358:254-255.
- Asnis D, Conetta R, Teixeira A, Waldman G, Sampson B. The West Nile virus outbreak of 1999 in New York City. *Clin Infect Dis*. 2000;30:413-418.
- Han L, Popovici F, Alexander J, et al. Risk factors for West Nile virus infection and meningoencephalitis, Romania, 1996. *J Infect Dis*. 1999;179:230-233.
- Petrov V, Krasnova Y, Lvov D, et al. Clinical picture and epidemiology of West Nile fever in Volgograd Oblast (1999 and 2000) [in Russian]. *Moscow Voprosy Virusologii*. 2001;45:22-26.
- Centers for Disease Control and Prevention. West Nile virus activity—United States, August 8-14, 2002, and Mississippi, July 1-August 14, 2002. *MMWR Morb Mortal Wkly Rep*. 2002;51:708-709.
- Nash D, Mostashari F, Fine A, et al. The outbreak of West Nile virus infection in the New York City area in 1999. *N Engl J Med*. 2001;344:1807-1814.
- Martin D, Biggerstaff B, Allen B, et al. Use of immunoglobulin M cross-reactions in differential diagnosis of human flaviviral encephalitis infections in the

United States. *Clin Diagnostic Lab Immunol*. 2002;9:544-549.

13. Martin D, Muth D, Brown T, et al. Standardization of immunoglobulin M capture enzyme-linked immunosorbent assays for routine diagnosis of arboviral infections. *J Clin Microbiol*. 2000;381:823-826.

14. Centers for Disease Control and Prevention. Acute flaccid paralysis associated with West Nile virus infection—Mississippi and Louisiana, July-August 2002. *MMWR Morb Mortal Wkly Rep*. 2002;51:825-828.

15. Sejvar J, Leis A, Stokic D, et al. Acute flaccid paralysis associated with West Nile virus infection. *Emerg Infect Dis*. 2003;9:788-793.

16. Southern P, Smith J, Luby J, et al. Clinical and laboratory features of epidemic St Louis encephalitis. *Ann Intern Med*. 1969;71:681-689.

17. Monath T, Brinker K. The acute disease. In: Monath T, ed. *St. Louis Encephalitis*. Washington, DC: American Public Health Association; 1980:503-544.

18. Wasay M, Diaz-Arastia R, Suss R, et al. St Louis encephalitis: a review of 11 cases in a 1995 Dallas, Texas, epidemic. *Arch Neurol*. 2000;57:114-118.

19. Huang C, Liu C, Chang Y, et al. Neurologic complications in children with enterovirus 71 infection. *N Engl J Med*. 1999;341:936-942.

20. Goh K, Tan C, Chew N, et al. Clinical features of Nipah virus encephalitis among pig farmers in Malaysia. *N Engl J Med*. 2000;342:1229-1235.

21. Weiss D, Carr D, Kellachan J, et al. Clinical findings of West Nile virus infection in hospitalized patients, New York and New Jersey, 2000. *Emerg Infect Dis*. 2001;7:654-658.

22. Shieh W, Guarner J, Layton M, et al. The role of pathology in an investigation of an outbreak of West Nile encephalitis in New York, 1999. *Emerg Infect Dis*. 2000;6:370-372.

23. Pradhan S, Pandey N, Shashank S, Gupta R, Mathur A. Parkinsonism due to predominant involvement of substantia nigra in Japanese encephalitis. *Neurology*. 1999;53:1781-1786.

24. Shoji H, Watanabe M, Itoh S, Kuwahara H, Hattatori F. Japanese encephalitis and parkinsonism. *J Neurol*. 1993;240:59-60.

25. Murgod U, Muthane U, Ravi V, Radhesh S, Desai A. Persistent movement disorders following Japanese encephalitis. *Neurology*. 2001;57:2313-2315.

26. Misra U, Kalita J. Movement disorders in Japanese encephalitis. *J Neurol*. 1997;244:299-303.

27. Misra U, Kalita J. Prognosis of Japanese encephalitis patients with dystonia compared to those with parkinsonian features only. *Postgrad Med*. 2001;78:238-241.

28. Hokkanen L, Launes J. Cognitive outcome in acute sporadic encephalitis. *Neuropsychol Rev*. 2000;10:151-167.

29. Gordon B, Selnes O, Hart J, et al. Long-term cognitive sequelae of acyclovir-treated herpes simplex encephalitis. *Arch Neurol*. 1990;47:646-647.

30. Solomon T, Vaughn D. Pathogenesis and clinical features of Japanese encephalitis and West Nile virus infections. In: Mackenzie J, Barrett A, Deubel V, eds. *Current Topics in Microbiology and Immunology: Japanese Encephalitis and West Nile Virus Infections*. Vol. 267. Berlin, Germany: Springer-Verlag; 2002:171-194.

31. Leis A, Stokic D, Polk J, Dostrov V, Winkelmann M. A poliomyelitis-like syndrome from West Nile virus infection. *N Engl J Med*. 2002;347:1279-1280.

32. Glass J, Samuels O, Rich M. Poliomyelitis due to West Nile virus. *N Engl J Med*. 2002;347:1280-1281.

33. Modlin J, Coffey D. Poliomyelitis, polio vaccines, and the post-polio syndrome. In: Scheld W, Whitley R, Durack D, eds. *Infections of the Central Nervous System*. Philadelphia, Pa: Lippincott-Raven Publishers; 1997:57-72.

34. Alcock A, Hildes J, Kaufert, et al. Respiratory poliomyelitis. *CMAJ*. 1985;130:1305-1310.

35. Tzeng S. Respiratory paralysis as a presenting symptom in Japanese encephalitis—a case report. *Chinese Med J*. 1989;43:208-212.